CAMBRIDGE TECHNICALS

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CAMBRIDGE TECHNICALS LEVEL 3 (2016)

Examiners' report

ENGINEERING

05822–05825, 05873

Unit 3 January 2024 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

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Unit 3 series overview

This Level 3 paper examined the principles of mechanical engineering. It followed a similar format to previous papers.

To do well on this paper, candidates needed to:

- be familiar with, and make appropriate use of, the contents of the formula booklet provided
- be familiar with all the parts of the specification examined
- be familiar with, and make use of, engineering language and terms
- show clear and legible workings especially for 2, 3, 4 and 5 mark questions
- attempt all questions.

The paper appeared to be accessible with most questions being attempted by candidates from many centres. However, many candidates demonstrated limited knowledge of the names of pulley belts, understanding bending moment diagrams and applying their understanding of energy transfer to an unfamiliar scenario.

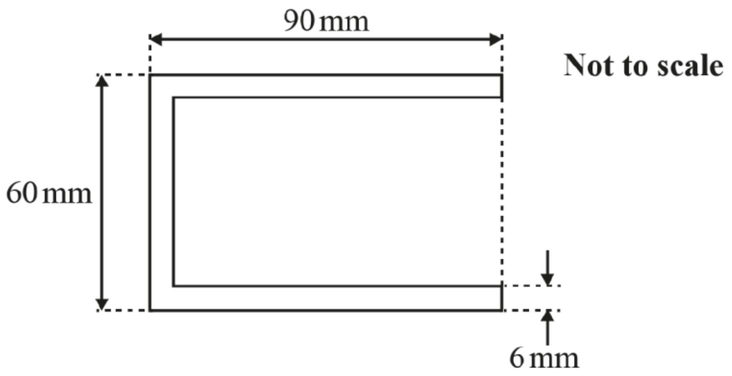
Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• attempted all questions • converted units correctly • rearranged equations correctly • used the formula booklet well • showed clear working out in calculations • used correct engineering terms correctly • were able to interpret diagrams well.	• did not convert prefixes for units correctly • applied equations incorrectly • did not draw or label diagrams correctly.

Question 1 (a) (i)

1

(a) **Fig. 1** shows the cross-section of a piece of aluminium framework. The aluminium has a uniform thickness of 6 mm, a uniform width of 90 mm and a uniform height of 60 mm. The length is 2500 mm.

Fig. 1



(i) Calculate the volume of the aluminium framework in $kg\,m^{-3}$.

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.... **[2]**

For this question, we updated the mark scheme to allow full marks for an accurately calculated volume whether candidates used the correct units of volume (m^3 or mm^3) or the unit of density which was incorrectly given in the question. All candidates attempted this question and most gave the correct units of volume (mm^3 or m^3) as their answer. Some candidates were unable to calculate the area, and subsequently the volume, accurately.

Question 1 (a) (ii)

(ii) The mass of the framework is 9.268 kg.

Calculate the density of the aluminium.

....

.... **[2]**

The mark scheme allowed an error carried forward from part (a) (i) so most candidates scored full marks for this question.

Question 1 (a) (iii)

(iii) An engineer changes the material of the framework to mild steel, which has a density of $7860\,kg\,m^{-3}$.

Assuming that the cross-section and length of the framework remain the same calculate its **additional** mass.

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....

....

.... **[3]**

Again, the mark scheme allowed an error carried forward from part (a) (i) so most candidates scored at least 2 marks. Some did not calculate the additional mass despite having correctly calculated the overall mass.

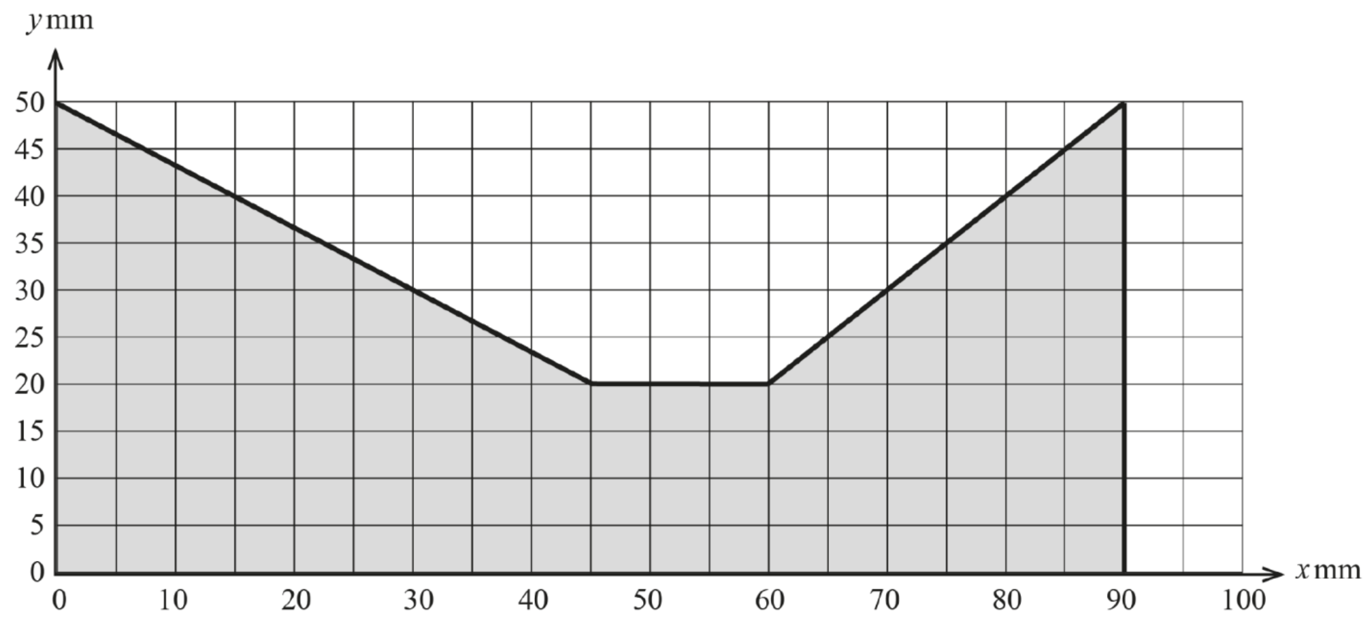
"Words in bold"

Words in bold are designed to draw candidates' attention to what the question is asking for.

Question 1 (b)

(b) **Fig. 2** shows a steel plate aligned within a Cartesian coordinate system (x, y). The units for both x and y are in millimetres.

Fig. 2



Calculate the coordinates of the centroid of the plate.

.... **[5]**

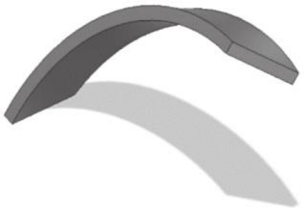
Candidates were expected to recall how to use the moment of area of uniform regular 2D shapes to find the position of the centroid of a more complex uniform shape. Many candidates split the shape into five separate areas rather than three and as a result had more opportunities to make errors in their subsequent working. However, most were able to score the first mark for calculating the area of the shape correctly. Those candidates who did not score full marks had usually calculated the x and y values of the centroids for both triangles incorrectly. Questions like this have been seen in many previous papers and it seems that many centres have made sure that candidates were well prepared for questions of this type.

Assessment for learning

Mark schemes for previous papers are available and centres are reminded that these, together with the specification, provide a valuable resource in preparing candidates for examinations.

Question 2 (a) (i)

2
(a)
(i) State the name of each pulley belt shown below.



A

B

C

A ....

B ....

C ....

[3]

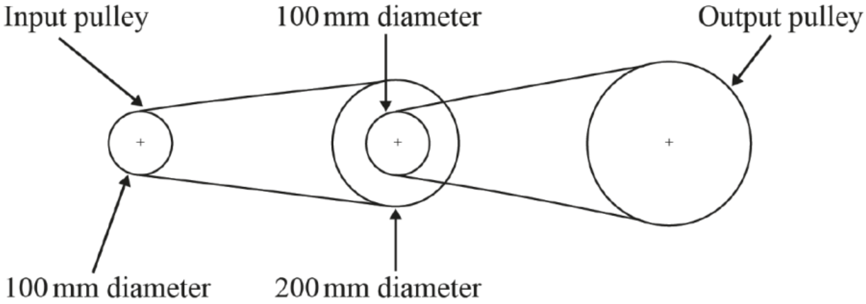
Many candidates were unable to name all three types of pulley belt correctly, and a sizeable minority were unable to name any of them.

Assessment for learning

The specification is very clear about these three types of pulley belts, so it is worth checking schemes of work to make sure they are included.

Question 2 (a) (ii)

(ii) This compound pulley system requires an overall velocity ratio of 0.2.



Not to scale

Calculate the diameter of the output pulley.

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.... **[3]**

The majority of candidates calculated the diameter of the output pulley incorrectly as they only considered the input and output pulleys and made no allowance for the middle pulley. They were therefore only able to score 1 mark out of the 3 available.

Question 2 (b) (i)

(b) An engineer has designed a class one lever that will lift a 50 kN load off the floor. This load is positioned 0.5 m from one side of the fulcrum. A vertical input force, F kN, is to be applied 3.5 m from the other side of the fulcrum and to be of sufficient magnitude to lift the 50 kN load.

(i) Draw a diagram of this lever showing:

- the position and direction of the load force
- the position and direction of the input force
- the distance of the load and input force from the fulcrum.

[2]

Most candidates scored at least 1 mark for the position and direction of the input force. The direction of the load force should have been downwards, and a lot of candidates showed this as acting upwards.

Assessment for learning

Some candidates drew diagrams which showed the force arrows and distances from the fulcrum not coinciding. Centres should reinforce the importance of accurately drawing and annotating diagrams.

Question 2 (b) (ii)

(ii) Calculate the minimum magnitude of the input force, F, required to lift the 50 kN load.

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.... **[2]**

This was answered well, especially as the answer could be given in N or kN.

Question 3 (a)

3

(a) **Fig. 3** shows a simply supported beam with one uniformly distributed load (UDL) of $3\,kN\,m^{-1}$ at the position indicated.

Fig. 3

Calculate the magnitude of the equivalent point load for the UDL and its distance from the left-hand support.

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....

....

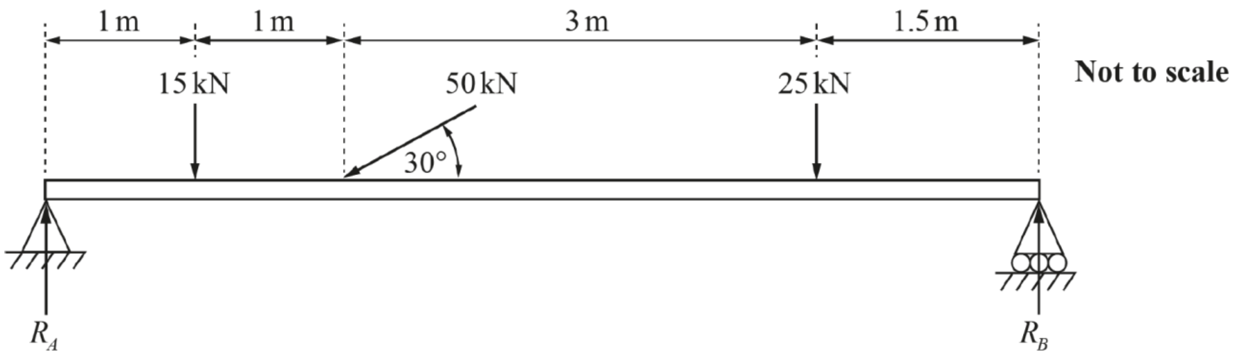
.... **[2]**

This caused confusion for some candidates who found interpreting the diagram challenging. However, for those that were able to calculate the equivalent point load correctly, most were able to gain the second mark for the distance from the left-hand support as well.

Question 3 (b) (i)

(b) **Fig. 4** shows a simply supported beam with three point loads.

Fig. 4



(i) Calculate the vertical component of the 50 kN point load.

....

.... **[2]**

This was answered well by most candidates.

Question 3 (b) (ii)

(ii) Calculate the magnitude of the two vertical reaction forces R_A and R_B.

The self-weight of the beam can be ignored.

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.... **[4]**

While many candidates were able to calculate the moments due to the three downward vertical forces, there were mistakes made in what these were equal to, with a sizeable number of candidates equating them to 1 R_A or 1 R_B, rather than 6.5 R_A or 6.5 R_B. Those candidates who scored full marks often worked both R_A and R_B out using moments, rather than equating the forces in an upwards and downwards direction. While this is a perfectly correct method, it does have the potential for greater errors.

Question 3 (b) (iii)

(iii) Draw a labelled bending moment diagram for the beam in **Fig. 4** on the grid below.

[5]

Candidates were required to recall the form of bending moment diagrams and to calculate values at key points. They were then required to sketch the bending moment diagram. A very small number of candidates scored full marks. The most common mistake in labelling the diagram was to show the calculated values as a force in (k)N, rather than as a bending moment in (k)Nm. Many candidates seemed unfamiliar with bending moments diagrams and scored 0 marks.

Assessment for learning

Centres should make sure that candidates are familiar with bending moment diagrams for the simple beam types and are able to calculate bending moment at key points in their diagrams. They must also be made aware of the importance of labelling axes with the correct quantities and units.

Question 4 (i)

4 An engineer is designing a steel structure with a safety factor of 2.5. Each steel column has an ultimate tensile stress of 400 MPa.

(i) Calculate the allowable working stress of the steel columns.

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....

.... **[2]**

This was extremely well answered with most candidates achieving full marks.

Question 4 (ii)

(ii) The column is subjected to an axial compressive force of 12 000 kN.

Calculate the cross-sectional area of the column using the ultimate tensile stress of 400 MPa.

Give the units of your answer.

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.... **[4]**

The most common mistakes were incorrect or no units for the area, using the incorrect stress value calculated in part (i), rather than the UTS given in this part of the question, or for incorrectly converting the two values to the same power of ten. Most candidates scored well on this question.

Question 5 (a) (i)

5

(a) A cannon is positioned 15 m above horizontal ground and fires a ball horizontally at a speed of 200 m s^{-1}. The motion of the ball is modelled as a projectile under the influence of gravity.

(i) By first finding the time taken for the ball to reach the ground, calculate the horizontal distance it travels during this time. Air resistance can be ignored.

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.... **[5]**

Many candidates used the incorrect horizontal value of velocity to calculate the time taken for the ball to fall vertically and thus calculated the incorrect time. Allowance was made for using the incorrect time in calculating the horizontal distance travelled, but many candidates thought the horizontal velocity changed from 200ms^{-1} to 0 ms^{-1} so no marks were gained for the distance, even allowing for the previous error in the time calculation.

Question 5 (a) (ii)

(ii) The mass of the ball is 5.4 kg and the mass of the cannon is 100 kg.

Using the conservation of momentum principle calculate the recoil speed of the cannon.

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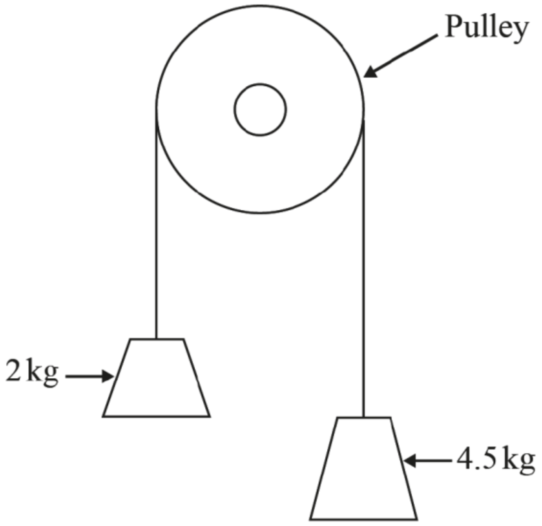
.... **[2]**

This part of the question scored the most marks with most candidates scoring at least 1 mark for equating momentum. Those who only scored 1 mark usually made an error in their division.

Question 5 (b)

(b) **Fig. 5** shows two masses of 4.5 kg and 2 kg held in suspension by a light inextensible cable on opposite sides of a frictionless pulley. When the masses are released the 4.5 kg mass accelerates downwards and the 2 kg mass accelerates upwards.

Fig. 5



Using the principle of conservation of energy calculate the speed of the masses when they have travelled 0.5 m. The inertial energy of the rotating pulley can be ignored.

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.... **[5]**

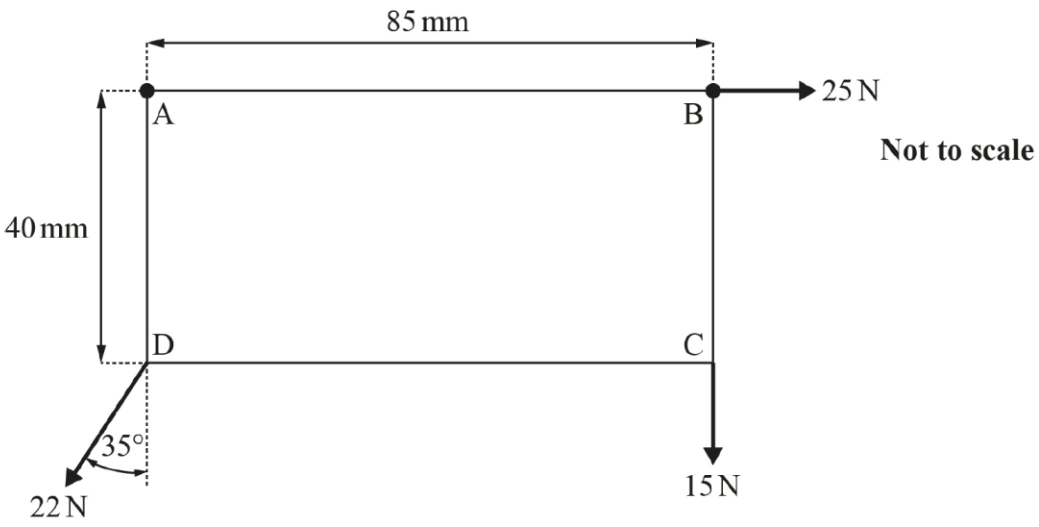
This was the least well answered question on the paper, with a sizeable number of candidates not attempting this at all or attempting very little. The question asks for the principle of conservation of energy to be used and so the decrease in gpe should be equated to the gain in ke. Very few candidates appreciated that there was an overall loss in gpe and so added the two gpe values together, rather than subtracting them. They also ignored the fact that the 2 kg mass was moving, so often just used the 4.5 kg mass to calculate the gain in ke. Apart from 0, the most common mark was 2; 1 mark gained for equating the (incorrect) energies and 1 mark gained for making v^2 the subject. Very few candidates scored full marks. Those candidates who did calculate the correct answer using F=ma and suvat equations were penalised 1 mark for not equating the energy.

Assessment for learning

Centres should make sure that candidates are familiar with this type of energy conservation example in addition to the more familiar objects rolling/falling/moving up and down heights.

Question 6 (i)

6 This diagram shows three coplanar forces acting on a rectangular steel plate, A B C D, in a vertical plane.



(i) Calculate the magnitude and direction, relative to the horizontal, of the resultant of the three forces acting on the plate.

You should first resolve the force at D into its perpendicular components.

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.... **[5]**

There were a sizeable number of candidates who were able to calculate the horizontal and vertical components of the 22 N force using the correct trigonometry. However, many then did not calculate the overall horizontal or vertical forces and so scored no marks. For those candidates who did gain the first 2 marks, there were a number that then did not calculate the resultant force correctly by using Pythagoras. Some candidates who scored 3 marks then did not calculate the direction of the resultant force relative to the horizontal.

Assessment for learning

Candidates need to be aware that when a direction is asked for in a vector quantity, an angle is required to be calculated, rather than purely a description given. Down to the right is not sufficient.

Question 6 (ii)

(ii) Calculate the moment acting about point A.

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....

.... **[2]**

Very few candidates scored both marks with most scoring 0. Those candidates that scored 1 mark usually did not state the direction of the moment for the second mark. Most candidates did not appreciate that there were 2 moments acting about point A, the horizontal component of the force acting at D and the vertical force acting at C.

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